

The Effectiveness of Mathematics 2.0 Learning through Digital Educational Games in Stimulating Early Childhood Mathematical Abilities

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Abstract

Mathematics 2.0 is a combination of mathematics and technology, which is essential due to the significant role mathematics plays in advancing technology, science, and education. This study aims to examine the effectiveness of Mathematics 2.0 learning through digital educational games in stimulating early childhood mathematical abilities. A mixed-methods approach was employed, utilizing qualitative methods to illustrate the importance of mathematics learning through educational games for young children, and quantitative methods to measure the impact of such games on stimulating early mathematical skills. The sample consisted of 30 early childhood students, with data collected through interviews and observations. The results of the study indicate that educational games such as Lumio and ScratchJr have a significant effect in stimulating mathematical abilities in early childhood.

Keywords: Mathematics 2.0; Digital Educational Games; Mathematical Abilities; Early Childhood

1. Introduction/Pendahuluan – Isi bisa dalam bahasa Indonesia

Early childhood education is a developmental process aimed at nurturing children from birth to six years old by providing appropriate stimulation to support their optimal growth and development (Diana & Mesiono, 2016). According to the 2022 Programme for International Student Assessment (PISA) released by the Organization for Economic Co-operation and Development (OECD), Indonesian students scored 366 points in mathematics, which represents a decline from the 2015–2018 assessments. This score is significantly below the OECD average, which ranges from 465 to 475 points. With a score of 366, Indonesian students were categorized at level 1a in mathematics proficiency in 2022. These data indicate that mathematical abilities must be stimulated as early as possible, considering mathematics is a foundational subject for advanced learning and a core component in various fields of study. Early mathematical proficiency helps children understand more complex concepts in the future and supports the development of structured and systematic thinking patterns.

The issue of low mathematical abilities in early childhood can stem from various internal and external factors. One major factor is the lack of stimulation and learning experiences. Many children have limited exposure to activities involving mathematics. Furthermore, teaching methods are often overly formal and inappropriate for young learners, hindering their understanding. At the age of 5–6, children begin to develop logical thinking skills in mathematics. However, a common challenge faced by teachers is that many children dislike mathematics, perceiving it as a difficult subject filled with numbers and formulas, which makes it hard for them to engage and understand (Suripatty et al., 2019).

Children require frequent practice and hands-on experience to grasp basic mathematical concepts. Enhancing mathematical abilities is crucial, as it enables individuals to think effectively and critically in a data-driven and numerically-oriented society (Nababan et al., 2024). Mathematics in early childhood plays a significant role in

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cognitive development and overall intelligence formation. Thus, mathematics should not be limited to counting, addition, subtraction, multiplication, or division, but should be seen as an integral part of a child's everyday life (Alfantiya & Hartati, 2023).

Ideal learning refers to the achievement of educational goals in a manner that stimulates children's potential development. One key tool for teachers is the use of engaging and relevant instructional media, particularly technology-based media aligned with the demands of the Industrial Revolution 4.0. However, in practice, many kindergarten teachers still struggle to innovate or utilize effective digital media in their teaching processes (Zulminiati et al., 2023). One strategy to address this is to increase children's interest and motivation in learning through the use of digital media. Children who are familiar with technology from an early age will be better prepared to meet 21st-century challenges.

The mathematical concepts introduced at the early childhood education (ECE) level serve as crucial foundations for understanding more advanced topics in later education (Rachmiati, 2024). As facilitators, teachers must possess a high level of self-efficacy in both planning and conducting mathematics-related activities in the classroom. The more confident a teacher is about the importance of early mathematics education, the better the learning approach they will design (Şeker & Alisinanoğlu, 2015). Teachers play a key role in identifying mathematical opportunities through play, scaffolding children's learning experiences, and avoiding overly formal methods of instruction (Clements, 2014). Parents also play a crucial role—not only as companions but as primary motivators in a child's learning journey (Hardika Saputra, 2024).

2. Digital Games

Currently, the development of quality human resources requires learning strategies that foster the emergence of higher-order thinking skills (HOTS) from early childhood through higher education (Salim, 2024). The rapid advancement of technology poses both a challenge and an opportunity to effectively support children's numeracy learning. This advancement must be utilized wisely to avoid negative impacts (Ismawati & Puspita, 2024).

Digital games are now recognized as meaningful and valid forms of play for today's children. These games are not only entertaining but can also serve as tools that promote cognitive, social, and creative development when used appropriately (Marsh et al., 2016). As children's play habits evolve in the digital era, the classification of games must also be updated to remain relevant. The emergence of interactive applications and media has led to new forms of play that are not captured by traditional frameworks. Therefore, educators must continuously review and adjust these frameworks to reflect the dynamic nature of children's play in the digital age.

A crucial first step for teachers is to design a comprehensive and well-planned approach and ensure that the selected technologies are age-appropriate and aligned with children's developmental stages (Salim, 2024). Integrating technology and play into learning provides a new approach that resonates with young children's natural tendencies toward play and curiosity (Maromi & Fitri, 2024). The use of mobile devices in kindergarten mathematics instruction has proven effective in enhancing children's comprehension. Children show greater enthusiasm and are better able to grasp mathematical concepts—such as measurement and geometry—through mobile-based activities (Papadakis et al., 2021).

The use of the Smart Game application has significantly improved preschool children's numeracy skills, reaffirming that game-based technology can be an effective tool in early childhood education (Sela Nurlaela et al., 2024). Since children are naturally drawn to games, digital educational games represent a strategic means of offering novel learning experiences (Setiawan et al., 2019). These games often blend education and entertainment—commonly referred to as edutainment—which can enhance engagement and sustain children's attention more effectively than conventional learning activities (Anis et al., 2024). Despite the major role of technology, teachers remain central in facilitating learning, ensuring that children use applications appropriately and understand the material correctly (Zaranis et al., 2013). Additionally, parents' ability to use online mathematics learning applications is also vital, particularly during at-home learning periods (Muanifah et al., 2021).

This research is noteworthy as it presents an innovative approach to Mathematics 2.0 instruction, which not only emphasizes cognitive aspects but also considers all dimensions of early childhood development. Therefore, the study is expected to provide new insights and practical solutions for teachers striving to create enjoyable and effective mathematics learning experiences. Previous research by Suryana et al. (2023) found that the development of

interactive games can enhance mathematical intelligence among kindergarten children. Similarly, a study by Listiawan & Antoni (2021) explored the development of augmented reality-based mathematics learning media for geometric transformation topics.

3. Research Method and Materials

The research employed a mixed-methods approach, integrating both quantitative and qualitative methods to obtain a comprehensive understanding of the effectiveness of Mathematics 2.0 learning for early childhood through digital technology. This approach began with the collection and analysis of quantitative data, followed by the collection and analysis of qualitative data.

The quantitative data were used to demonstrate that Mathematics 2.0, implemented through educational games, can enhance children's mathematical understanding. In contrast, the qualitative data were utilized to explore in depth how children, educators, and parents perceive the benefits of Mathematics 2.0 through such digital educational games. The qualitative findings served to explain and enrich the results obtained from the quantitative analysis.

4. Results and Discussion

4.1. Results

Quantitative data analysis employed non-parametric tests, considering the sample size of 30 children. The use of non-parametric methods was deemed appropriate due to the relatively small sample size and the potential for data not meeting the assumptions of normality. The results shown on Table 1.

Table 1. Wilcoxon Signed Ranks Test Results for ScratchJr Game

Ranks		N	Mean Rank	Sum of Ranks
Pretest – Pos Test Game 1	Negative Ranks	0 ^a	.00	.00
	Positive Ranks	30 ^b	15.50	465.00
	Ties	0 ^c		
	Total	30		
Test Statistics^a				
Z	Pretest – Postest game 1			
Asymp. Sig. (2-tailed)	-4.824 ^b			<.001

Based on the Table 1, the test yielded a Z-value of -4.824 with an asymptotic significance (2-tailed) of < 0.001. This significance level, being less than 0.05, indicates that there is a statistically significant difference between the pretest and posttest scores. Therefore, it can be concluded that there was an improvement in mathematical ability following the intervention with the ScratchJr Game, suggesting that the treatment had a significant impact on children's learning outcomes.

Based on the Table 1, a Z-value of -4.810 was obtained with an asymptotic significance (2-tailed) of < 0.001. This result indicates a statistically significant difference between the pretest and posttest scores. Since the significance value is less than 0.05, it can be concluded that the implementation of the Lumio Game had a significant effect on improving children's learning outcomes.

The quantitative data analysis showed that Mathematics 2.0 through digital educational games had a significant positive impact on early childhood mathematical abilities.

The qualitative data in this study describes how the implementation of educational games through Mathematics 2.0 can stimulate children's mathematical skills. Qualitative data were collected through in-depth interviews conducted with 7 teachers and 30 parents, revealing in detail the impact of applying Mathematics 2.0-based educational games—Lumio and ScratchJr—on children's mathematical development.

Table 2. Wilcoxon Signed Ranks Test Results for Lumio Game

Ranks		N	Mean Rank	Sum of Ranks
Pretest – Pos Test Game 2	Negative Ranks	0 ^a	.00	.00
	Positive Ranks	30 ^b	15.50	465.00
	Ties	0 ^c		
	Total	30		
Test Statistics^a				
	Pretest – Postest game 2			
Z		-4.810 ^b		
Asymp. Sig. (2-tailed)		<.001		

The organized qualitative findings, based on the perspectives of teachers and parents, indicate that both games enhanced children's engagement and learning motivation. Children who were previously passive became more active and enthusiastic when learning mathematics through Lumio and ScratchJr. In addition, teachers reported that these games facilitated the teaching of abstract concepts, such as introducing numbers as quantities.

From the parents' perspective, significant changes were observed in their children's attitudes toward mathematics. Children began to frequently request to "play math" using these games and even taught their younger siblings how to count using the same tools. Moreover, Lumio and ScratchJr stimulated children's creative thinking and helped them recognize patterns more quickly.

Observational data further revealed that children often experimented with various strategies to solve challenges in the games. Some also engaged in collaborative discussions to work through problems together.

4.2. Discussion

In today's rapidly evolving digital era, teaching methods have undergone a significant transformation. One such innovation is early childhood mathematics learning through the use of digital educational games as interactive media to stimulate young children's mathematical abilities. Educational games not only make learning mathematics more enjoyable, but they also enhance conceptual understanding, logical thinking skills, and learning motivation. Children are more likely to absorb information effectively when they are engaged and having fun.

These educational games are designed with colorful visuals, animations, sound effects, and exciting challenges, making mathematics feel less intimidating. The games used in this study were ScratchJr and Lumio.

ScratchJr is specifically designed for children aged 5–7 years, enabling them to program their own interactive stories and games. Through this process, children learn to solve problems, design projects, and express themselves creatively using technology. ScratchJr can be described as a "technological playground" for young children (Leidl et al., n.d.). The application is freely available and can be downloaded across various platforms, including iOS, Android, Amazon tablets, and increasingly popular Chromebooks (Bers, 2018).

The implementation steps of ScratchJr Games in this study included:

- 1) Children begin by clicking the green flag icon to run their program.
- 2) Children experiment by tapping characters to see the effects of their coding.
- 3) Children can add new sprites or change backgrounds as they wish.
- 4) Children are free to choose activities, such as "jumping over numbers" or "guess the shape."

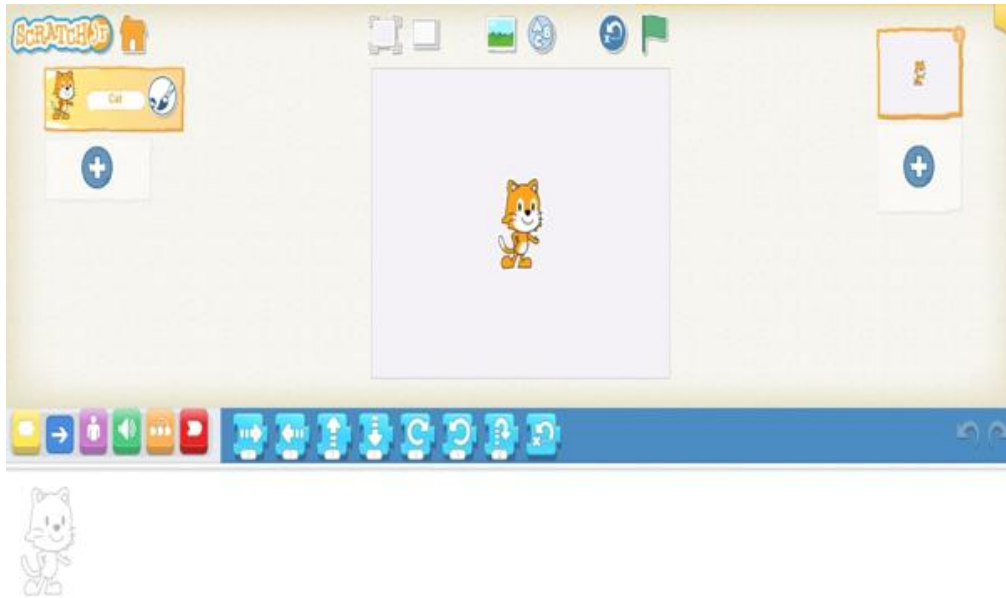


Figure 1. ScratchJr Games

ScratchJr enables young children to use programming blocks that control movement, appearance, sounds, character communication, and many other component features. Through these programming blocks, early learners can grasp basic concepts and develop great coding ideas while creating meaningful individual projects (Nurjanah et al., 2021). The achievement indicators for this game include the child's ability to recognize numbers and count objects concretely. Through the educational game ScratchJr, children can easily and enjoyably learn numbers interactively. During gameplay, they interact with numbers appearing in various activities such as counting the number of sprites and pressing numbers to move characters. Additionally, the block coding feature allows numbers to appear on layers when characters touch objects, which strengthens children's visual memory of numeric symbols. In this way, children not only memorize numbers but also understand their meaning in a creative game context. ScratchJr also enables teachers and parents to create counting challenges, such as asking children to collect a certain number of objects or tap numbers on the screen corresponding to the number of sprites. These activities train number recognition as well as the concept of quantity since they are packaged in the form of stories and games.

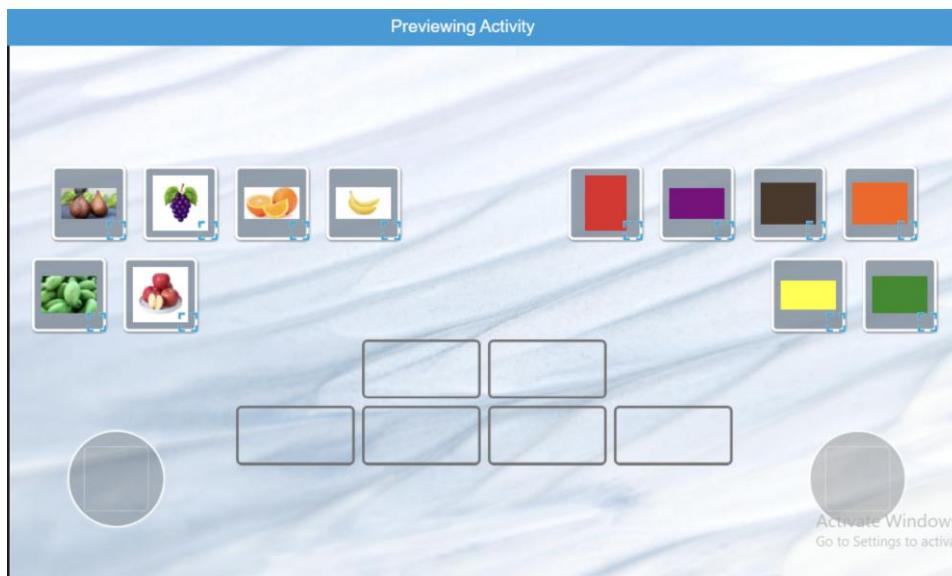


Figure 2. Lumio Games

Lumio Game is an interactive digital learning platform developed by SMART Technologies, specifically designed to create enjoyable learning experiences for all ages, including early childhood. This platform incorporates elements of game-based learning to make learning activities engaging through math games or creative projects accessible via any device, including tablets, laptops, or smart boards. Lumio Game uses game elements such as points, levels, and challenges to motivate children to learn. It contains many math introduction activities, including number recognition, geometric shapes, patterns, and logic. Teachers and parents can track children's learning progress through reporting features. The use of the Lumio learning application can be applied not only in learning evaluation activities but also in the delivery of instructional material (Anton et al., 2024).

This study revealed that the use of both platforms significantly increased children's engagement. The children demonstrated higher enthusiasm when learning abstract concepts such as addition or subtraction because these were packaged as enjoyable game challenges. Moreover, the scaffolding provided by the support features in Lumio (e.g., visual cues) and the intuitive coding blocks in ScratchJr made it easier for children to understand mathematical concepts without feeling overwhelmed. The data also identified improvements in children's cognitive abilities, such as pattern recognition and spatial skills, which were stimulated through the progressive level design of the games.

5. Conclusion

Based on the findings from a mixed-method approach combining qualitative and quantitative data analysis, it can be concluded that the implementation of Mathematics 2.0 learning through the educational games Lumio and ScratchJr is proven effective in stimulating the mathematical abilities of early childhood children. The results indicate that educational games not only enhance motivation and active engagement in learning but also assist children in understanding abstract mathematical concepts. Children who used these games showed notable progress in mastering basic mathematical skills. This study confirms that well-designed and appropriately utilized digital educational games can serve as transformative tools in early childhood mathematics education, bridging the gap between conventional learning methods and the demands of the digital era.

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